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A COST ANALYSIS FOR DECIDING
SERVICE LEVELS IN KOREAN ARMY
WITH A CONSTRAINT FOR SINGLE PERIOD

by

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June 1990

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Since the Korean War there has been a fierce military competition between the Republic of Korea (ROK) and the Democratic People's Republic of Korea (DPRK). The DPRK has committed over 10 percent of its GNP since 1963 to defense expenditures, whereas, the ROK has spent a relatively small portion (3-6 percent) of GNP over the same period. Because the U.S. plans to withdraw from the ROK in the near future, a heavy burden will be imposed upon the ROK Government to maintain its national defense. The U.S. withdrawal will result in the delay of achieving a military balance in the Korean Peninsula. Under these conditions, it becomes essential to find the most efficient allocation of the defense budget so as to get the most high-tech weapons, and achieve military balance with the DPRK at the soonest possible time. The purpose of this thesis is to compute the service levels for critical items with the present budget, and to determine whether the budget is used effectively in the ROK Army. To solve the problem, the cost analysis method is utilized. An application of this methodology is shown with an illustration. This analysis shows that different items call for different service levels.

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ABSTRACT

Since the Korean War there has been a fierce military competition between the Republic of Korea (ROK) and the Democratic People's Republic of Korea (DPRK). The DPRK has committed over 10 percent of its GNP since 1963 to defense expenditures, whereas, the ROK has spent a relatively small portion (3-6 percent) of GNP over the same period. Because the U.S. plans to withdraw from the ROK in the near future, a heavy burden will be imposed upon the ROK Government to maintain its national defense. The U.S. withdrawal will result in the delay of achieving a military balance in the Korean Peninsula. Under these conditions, it becomes essential to find the most efficient allocation of the defense budget so as to get the most high-tech weapons, and achieve military balance with the DPRK at the soonest possible time. The purpose of this thesis is to compute the service levels for critical items with the present budget, and to determine whether the budget is used effectively in the ROK Army. To solve the problem, the cost analysis method is utilized. An application of this methodology is shown with an illustration. This analysis shows that different items call for different service levels.

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I. INTRODUCTION

The economies of all countries are becoming more interrelated. The developing world economy is complex and variable. Each country has to plan to solve its economic problems by itself.

Moreover, the more the world economy develops, the closer and more complex the world becomes. Because of this reason, the changes of one area influence the other areas very rapidly in many respects, such as the economy, the politics, the community, the culture, etc.

The efforts for detente between the United States (U.S.) and the Soviet Union and the collapse of the Berlin Wall in January 1990, indicated new changes in the European region. Also, the demonstration for democracy by the eastern Europeans portend new changes in the world economic and political balance.

This turn of events makes people in the U.S. believe that it is the time to solve their economic problems by decreasing the defense budget by withdrawing or reducing U.S. personnel and equipment not only in the continental United States (CONUS) but also in Western Europe and other foreign countries.

As a result, the U.S. government plans to close some military bases in CONUS and overseas. Among these bases are two Air Force bases in the Republic of Korea (ROK). These bases play a very important role in the defense of ROK from North Korea. Therefore, the ROK government is faced with the problem of preparing a new strategy for self-defense.

The strain of additional defense spending comes to ROK at a critical time, when it is becoming a developed country. The change of the U.S. defense strategy against the communist countries forces ROK to commit more actual funds and necessitates more efficient application of assets to achieve its new strategy.

In order to accomplish this, the following things must be accomplished:

- Modernization of the military forces of ROK
- Maintenance of the minimum military forces to prevent war in the Korean Peninsula

- Efficient management of war materials within the available budget

Since the modernization of military forces and force reductions are beyond the scope of this study, this thesis will focus on the efficient management of war materials.

The purpose of this thesis is to find the service levels of critical items in the ROK Army within the present budget, examine whether the budget is being used effectively, and show how the changes in the service level affect the budget. The cost analysis method is used to determine answers for these questions.

Chapter II describes the history and military competition between the two Koreas after the Korean war, and the effects of the U.S. withdrawal from the ROK.

Chapter III discusses the ROK logistics during the Korean War, introduces the inventory system of the ROK Army, and examines the problems and the methodology to solve them.

Chapter IV explains the cost analysis methodology and shows how to apply it to the real world by use of an illustration. Since the real data is not available from the ROK, some assumptions, simplifications, and approximations are used when applying the theory to the illustration.

Chapter V presents the conclusion. It emphasizes that for the self-defense of the ROK, the critical issue is to use the budget effectively. It also concludes that under a limited budget, we cannot achieve ZERO DEFECT SUPPORT for all critical items.

II. BACKGROUND

A. HISTORY

In November 1943 at the Cairo Conference, the Allied powers agreed that after the surrender of Japan, Korea should become "free and independent." In July 1945 this was reconfirmed by the Potsdam Declaration. However, the fate of Korea changed overnight. At the 1945 Yalta Conference, the leaders of the U.S., Great Britain, and the Soviet Union reached a secret agreement which included dividing Korea into two parts along the 38th parallel, in order to facilitate the disarmament of the Japanese Forces [Ref. 1: p. 409].

In spite of Korean objections, as soon as Japan surrendered on 15 August 1945 the Soviet Union dispatched its forces to the area north of the 38th parallel, in accordance with the Yalta agreement.

The Soviet Union established a military government which helped to solidify the North Korean Communist regime. The U.S. forces moved into the area south of the 38th parallel, and established another military government. The U.S. claimed, however, that the 38th parallel was not a political demarcation, but a temporary expedient to facilitate military operations. When the Soviet Union blocked efforts to reunite Korea, a conference of foreign ministers convened to settle the matter [Ref. 2: pp. 170-71].

An agreement was reached stating that Korea would become independent after a 5 year trusteeship of 4 countries: U.S., Great Britain, the Soviet Union and China. Although the Soviet Union agreed to this joint trusteeship, it never came into being because the Soviet Union moved to prevent it.

In 1947 the United Nations mandated that free elections should be held throughout the Korean Peninsula. The United Nations Temporary Commission on Korea was prevented from entering the area north of the 38th parallel, however. So on May 10, 1948, voting was conducted only in the southern half of the country, which was occupied by the U.S. The South Koreans formed the Republic of Korea (ROK) in May 1948, making Seoul the capital. The Republic was formally acclaimed on August 15, 1948. The first president was Rhee.

Meanwhile, in the north, Kim Il-Sung, previously situated in Pyongyang since October 1945 as the leader of the emigre forces, was trained by the Soviet Union to prepare for an eventual takeover. He established his dominance as premier when the Democratic People's Republic of Korea (DPRK) was set up in September 1948.

The U.S. forces were withdrawn from the ROK by mid-1949, and the new state was not included within the U.S./Asian defense perimeter. This contrasted sharply with a Soviet-supported military buildup that was taking place in the DPRK.

At the time of outbreak of the Korean War, on 25 June 1950, the DPRK Army numbered between 150,000 and 200,000 troops, vastly outnumbering the under-equipped forces of the ROK. Therefore, ROK forces were reinforced principally by U.S. troops, and by military units of other United Nations countries.

After three years of war, peace talks were initiated. On July 27, 1953, a cease-fire agreement was signed at the village of Panmunjom. No actual peace treaty has ever been worked out between the two sides, and thus north and south still remain in a technical state of war [Ref. 3: p. 529].

B. MILITARY COMPETITION

Military competition began early between the ROK and the DPRK. By February 1948, the DPRK established a full-fledged Soviet-style army with 200,000 regular soliders, including infantry, armoured troops, engineers, signals, ordinance and rear services.

Conversely, the ROK had about 50,500 soldiers in August 1948. It was modelled on the U.S. Army. Its main arms and services were then, and remain today, the infantry, armour, engineers, signal corps, ordinance corps, and quartermaster corps.

Arms transfer to the ROK and the DPRK played a significant role to strengthen and develop their military forces. Before they were able to produce arms, they were absolutely dependent on shipments from other countries, especially the U.S. for the ROK, and the Soviet Union for the DPRK.

1. Republic of Korea

Between 1945 and 1950, the ROK found itself part of the U.S. "forward defense areas." The U.S. approach to the ROK before the outbreak of the Korean War could best be described as ambivalent.

Because of the aggressive attitude of the Rhee government, which desired to reunify the Korean Peninsula, the U.S. Occupation Army equipped the ROK with only light arms and mortars, and provided some technical training. The U.S. took "the precaution to arm the ROK Army only with light defensive weapons to preclude any temptation to invade the DPRK [Ref. 4: p. 140].

The Koean War, which began on June 25, 1950 and ended on July 27, 1953, shifted the U.S. military assistance program for the ROK from limited assistance to direct intervention and massive aid. During this time, the ROK received tremendous amounts of military equipment.

This aid included over 800 tanks and the bulk of infantry weapons. It did not include any aircraft. The ROK forces relied totally on the U.S. for air support.

The ROK forces emerged from the war in marginally better condition than did those of the DPRK. Although the ROK Army was intact, it relied heavily on U.S. support. The ROK Air Force consisted only of limited numbers of older propeller-type aircraft, and the ROK Navy emerged from the war virtually unchanged.

After the Korean War, the armistice agreement prohibited the introduction of new weapons to the ROK, and froze combat aircraft at the existing level. This agreement did not last long.

From July 1953 through 1960, the U.S. policy was to provide nuclear deterrence, and to shift the burden of limited conventional deterrence to local forces. This caused the military aid to the ROK to rise steadily throughout the 1950's, peaking between 1958 and 1960 [Ref. 4: p. 410].

Actual arms transfers to the ROK during the 1950's were mostly World War II surplus items. Those were simple weapons which required only minimal maintenance and limited complex spare parts. Although they were outdated in the U.S., they filled the needs of the ROK Army and were commensurate with the ROK maintenance capabilities [Ref. 5: p. 238].

The 1960's can be divided into two parts: Pre-Vietnam War (1960-1965) and the Vietnam War Period (1965-1970). During this decade, the U.S. perception of the threat in Asia was transferred from the ROK to South East Asia. This led to a shift in U.S. military aid, which caused significant fluctuations in military aid to the ROK. The military aid to the ROK peaked in 1961, and not until 1968 did it again reach the previous high.

During this decade, the arms transfer to the ROK included the following advanced weapon systems: the Nike Hercules, Honest John, and Hawk missiles, sixty F-86 fighters and approximately 700 advanced Sidewinder air-to-air missiles.

In spite of the increased involvement of the U.S. in Vietnam in 1965, military aid to the ROK was not halted. In 1965 F-5 Freedom Fighters were delivered to the ROK to replace F-86's, in response to DPRK - created incidents along the cease-fire line and in the ROK itself. The DPRK also attacked U.S. forces: the USS Pueblo was captured and an EC-121 reconnaissance plane was shot down.

Aid for operations and maintenance increased significantly in 1969 and 1970. In 1969, $100 million was requested over and above the appropriations to update anti-aircraft systems, patrol boats, and radars. This also authorized a squadron of F-4E Phantoms [Ref. 4: p. 417].

In 1970's changes in the relationship between the ROK and the DPRK began. The most important event of the early seventies was the resumption of unification talks in 1972. These were culminated by the Joint Communique of July 4, 1972. Although these talks looked promising, they were virtually doomed from the start.

Moreover, President Park's (the third ROK president) reelection became a political issue in the U.S. Congress, and it resulted in a cut-back of military aid. Congress held true to its threat by approving only $146 million in military grants in 1975. An additional $20 million was withheld until the U.S. president was satisfied that political rights were restored [Ref. 6: p. 280]. This withheld aid was never subsequently allocated.

Events that transpired in 1975 and early 1976 caused the U.S. restriction to be lifted. A second tunnel was discovered under the demilitarized zone (DMZ) in 1975. The pivotal event, however, was the axe-slaying of U.S. Army personnel at Panmunjom on August 18, 1976. As a result, U.S. military aid to the ROK jumped from $146 million in 1975 to over $230 million in 1976.

An effort to upgrade the ROK forces was initiated in 1976 with the five year Force Improvement Plan (FIP). This plan was designed to reduce the deficiencies and to modernize the ROK forces with a $5.5 billion investment. Additionally, in 1979 the U.S. provided $275 million in Foreign Military Sales (FMS) credits.

During the 1970's, arms transfers were mostly for defensive arms. The only offensive air capability was provided by the 47 F-4D/E aircraft delivered in 1971-1977. The capabilities for ROK Army were improved by the transfer of over 500 M-48 tanks which the ROK converted to M-48 A-5's.

2. Democratic People's Republic of Korea

The Soviet Union entirely dominated the DPRK prior to the Korean War. They were the sole supplier of arms, ammunition, gasoline, vehicles and other military items. The Soviet aid is established to have been $56 million between 1945 and 1950 [Ref. 7: p. 241].

After the withdrawal of the Soviet Union in 1949, the DPRK was provided with continued large deliveries of tanks, trucks, artillery, and war planes [Ref. 4: p. 192].

Furthermore, the communist victory in the Chinese Civil War led to a shift of the Chinese support from ROK to DPRK. Nevertheless, due to the Civil War China was exhausted, and the Chinese Communists were unable to support the DPRK with war material. Thus, China played no significant role in arms transfers during this period.

During the Korean War, military aid to the DPRK consisted mainly of aircraft, tanks, and artillery. Although the DPRK received massive Soviet and Chinese support, their armed forces were decimated by the war. Their army suffered enormous casualties and equipment losses. Similarly, their Air Corps had to completely regroup and retrain due to the enormous losses suffered in the early stages of the war [Ref. 4: p. 411].

The period following the Korean War was used by Kim Il-Sung, the dictator of DPRK, to reconsolidate his political power. DPRK channeled most of their resentment -- generated by their failure in the Korean War -- toward the Soviet Union, because of their initiation of the armistice process.

Kim voiced his disapproval of the Soviets by embarking on an independent path of reconstruction without prior Soviet Union approval. These effects were greatly aided by the Chinese military presence in the DPRK until 1958. Despite this antagonism, the Soviet Union remained the sole supplier of major weapons, and thereby maintained greater influence through the summer of 1958 [Ref. 8: pp. 20-26].

The Soviets trained the North Koreans with modern equipment between 1955 and 1957. Once trained, the DPRK received 20 Il-28's in 1955 and 100 MIG-17's from 1956 to 1958. In 1959 China supplied the DPRK with 80 MIG-17's, and began delivery of Il-28's. Chinese support continued in 1958-1959 with the transfer of 44 Il-28's, 20 Yak-18's, and Shenyan F-4 aircraft. China also introduced the first supersonic aircraft, the MIG-19, to the DPRK in 1959. Between 1957 and 1960, China increased the DPRK naval capability with the transfer of 24 mine sweepers [Ref. 4: p. 364].

From 1953 to 1960 aid to DPRK shifted from being completely Soviet to being mostly Chinese. Consequently, the Chinese influence grew. The change was largely due to increased Chinese arms production capability, and resentment over Soviet pressure to accept the cease-fire.

The 1960's could be divided into two periods: stronger ties to China up to 1965, and thereafter a shift back to the Soviet Union. The DPRK concluded a mutual defense treaty with the Soviet Union in 1961. This was not an acceptance of Soviet dominance, however, for in this same year Kim introduced his Seven-year Economic Development Plan, defying a Soviet attempt to coordinate and direct all socialist planning efforts. The combination of defiance in economic planning, and the refusal to accept Soviet military command dominance, resulted in the cancellation of all Soviet aid [Ref. 4: p. 413].

Although the DPRK lost their Soviet support, they found wholehearted Chinese support in the early 1960's. China increased its supply of jet fuel and spare aircraft parts to the DPRK in the same period. The DPRK reciprocated by reorganizing its Air Force along Chinese lines. By 1963, the DPRK had received 400 Chinese built aircraft, including Shenyang 4 (MIG-17), MIG-15's, and Il-28's.

According to the Stockholm International Peace Research Institute, by 1964 the DPRK's Air Force had expanded to 465 combat aircraft. During the early sixties, the DPRK military strength exceeded the ROK's by 200-400 percent [Ref. 4: pp. 413-14].

From 1965 the relationship between the DPRK and the Soviet Union began to improve. After the meeting between Soviet premier Kosygin and Kim Il-Sung, Soviet support started to be increased again. Modern equipment soon was being shipped to the DPRK, included MIG-21's and SA-2's. Heavy equipment, including heavy field artillery, was provided for the DPRK ground forces to offset modernizations in the ROK Army [Ref. 4: p. 414].

As a result of substantial Soviet military aid, by 1967 the DPRK Air Force had over 500 combat aircraft, including 21 MIG-21's, 350 MIG-17's, 80 MIG-15's. Also provided were 10 Air-Defense complexes, including 500 SA-2 missiles. Almost all of DPRK's heavy army equipment was Soviet supplied [Ref. 8: p. 126].

The relationship with the Soviet Union was an important concern of the DPRK during the early and mid-seventies. Although the Soviet Union was

DPRK's major source of arms, its arms transfers and military assistance brought little increased influence [Ref. 9: p. 234].

China also remained important to the DPRK during the 1970's as a counterbalance to the Soviet domination. During the mid-seventies, China promised military aid in the form of tanks, torpedo boat, destroyers, submarines, and fighter planes. Chinese aid promises coincided with the victory by North Vietnam. Encouraged by these events, Kim apparently requested support from China to renew his war against the ROK [Ref. 8: p. 145].

However, China, like the Soviet Union, was interested in maintaining relations with the U.S. Thus, the Chinese response of peaceful reunification to Kim's request was met with polite silence.

Actual arms transfers in this period did little to improve their offensive capabilities. They received 28 SU-7 fighter bomber aircraft in 1971, and 2 squadrons of MIG-21's. The ground forces were supplied with 50 T-62 tanks in 1975.

Defensively, the DPRK fared better during this period. Its naval capability was increased with the introduction of SS-N-2 Styx missile. Likewise, the increased number of patrol boats and submarines gave them a better capability to defend their coast. In 1972, 200 SA-7 surface-to-air missiles were supplied thereby adding to its air defense capability.

Overall, during the seventies, arms transfers to the DPRK reflected the mood of the time -- detente. The support from the Soviet Union and China shifted toward defensive-oriented weapons.

C. THE EFFECTS OF U.S. WITHDRAWAL

The ROK has experienced better military and economic support than has the DPRK. However, their support was threatened in the early 1970's because of political differences with its supplier, the U.S.

In 1974, the U.S. Congress was on the verge of cutting aid to protest the political situation in the ROK when an assassination attempt by a DPRK agent was made on President Park. Park escaped, but his wife was killed [Ref. 10:

pp. 206-07]. This event stayed the U.S. Congress from severely cutting aid to the ROK.

President Nixon's proclamation of a new U.S. defense policy in 1969 and the subsequent withdrawal of the U.S. 7th Division from the ROK, pushed the ROK toward local production of arms in the mid-seventies [Ref. 11: p. 15].

President Carter's 1977 decision to withdraw all U.S. ground forces from the ROK, although later rescinded, increased ROK's fears vastly. This led to increased emphasis by the ROK to rapidly develop its arms production industries [Ref. 12: p. 154].

Today the U.S. withdrawal has again become a big issue to the DPRK as well as to the ROK. When and how many U.S. forces will be withdrawn from the ROK is a concern to both nations. Because of the U.S. withdrawal, the DPRK will lose an important political issue against the ROK, the U.S., and their own people. The ROK is also concerned about the necessary increase in the budget for national defense.

In January 1990 the Bush administration submitted a budget plan with decreased national defense expenditures, which included a reduction of a number of military forces and bases. This plan proposed that two of the U.S. Air Force (USAF) bases in the ROK would be closed by 1992. The USAF, however, has played a more important role to keep the peace in Korean Peninsula than has the U.S. ground forces. Since the reduction of the USAF assets in the ROK could mean the beginning of a complete U.S. withdrawal, the ROK has the burden of rebuilding the self-defense system in a short period of time.

When the U.S. withdrawal is completed, by the analysis of the ROK Ministry of National Defense (MND), it will cost more than $5.2 billion to get the replacement strength. This means that the sum of added cost along with the present expenditure for the national defense will be up to 8 percent of GNP, which is 50 percent increase over current levels.

The effect of the U.S. withdrawal will appear in other respects besides the increased budget for the national defense. According to the MND, in 1989 the strength ratio, which compares ROK forces with those of DPRK, was 66 percent for ROK by itself, and only 72 percent when the resident U.S. forces were included. With the present budget level, it will be maintained at 80 percent ROK only and at 86 percent with the U.S. forces in 1996, assuming an expenditure of S 62.6 billion by 1996. Table 1 shows the trends comparing ROK and DPRK military power.

Table 1. COMPARISON OF MILITARY POWER BETWEEN ROK AND DPRK (PERCENTAGE OF DPRK, DPRK= 100)

YEAR	'80	'81	'82	'83	'84	'85
ARMY	59.1	59.3	59.6	61.3	63.8	60.9
NAVY	49.7	49.3	53.1	59.5	55.8	59.4
A.F.	42.0	43.8	51.1	51.9	52.7	59.9
TOTAL	53.8	54.2	56.6	59.1	60.2	60.5

While the ROK economy has made excellent progress, defense spending is reaching about 6 percent of GNP or approximately one third of the government budget. This figure is considered high by free-world standards. Despite this high level of spending, the imbalance of military power between ROK and DPRK remains in favor of DPRK as shown table 1 [Ref. 13: p. 20].

Table 2 shows the comparative expenditures between ROK and DPRK from 1952 to 1986. This table reveals that since 1963, DPRK has committed over 10 percent of its GNP to defense expenditures, whereas, in the same period the ROK has committed a relatively small portion (3-6 percent) of GNP.

As the U.S. withdrawal approaches, the cost of modernizing the military and obtaining the higher operating efficiency becomes a major issue.

Table 2. ROK-DPRK COMPARATIVE MILITARY EXPENDITURES, 1952-1986 (UNIT : MILLIONS OF U.S. DOLLARS)

YEAR	ROK			DPRK		
	EXP.	% GNP	% BUD.	EXP.	% GNP	% BUD.
1952	67	N/A	N/A	N/A	N/A	N/A
1953	154	5.7	10.1	75.4	N/A	15.2
1954	185	6.6	11.5	58.4	N/A	8.0
1955	151	5.1	10.9	61.3	N/A	6.2
1956	145	4.7	11.4	56.4	N/A	5.9
1957	146	5.8	13.7	54.2	N/A	5.3
1958	172	6.2	14.3	56.8	N/A	4.8
1959	180	6.4	15.8	61.0	N/A	3.7
1960	178	6.1	15.7	61.0	N/A	3.1
1961	185	5.7	19.2	275	N/A	2.6
1962	213	5.9	25.3	305	N/A	2.6
1963	177	4.2	14.9	280	12.2	1.9
1964	167	3.6	10.7	300	12.0	5.8
1965	175	3.7	11.6	350	14.0	10.1
1966	214	4.0	13.7	350	12.1	12.5
1967	238	4.1	14.2	470	15.7	30.4
1968	281	4.2	16.4	610	17.4	32.4
1969	324	4.1	17.8	615	15.4	31.0
1970	334	3.9	17.0	700	15.0	31.0
1971	394	4.3	17.3	911	17.1	34.1
1972	443	4.4	18.2	584	13.8	17.0
1973	470	3.9	13.3	630	14.0	15.4
1974	601	3.2	15.6	765	15.8	16.1
1975	730	3.8	18.0	950	16.3	16.4
1976	1460	6.2	19.5	1030	11.2	16.7
1977	2033	6.6	19.1	1060	10.5	16.6
1978	2586	5.6	19.0	1230	11.4	16.0
1979	3219	6.4(est)	N/A	2900	20.6	15.0
1980	4400	6.1	33.2	N/A	N/A	N/A
1981	4500	7.1	N/A	1700	9.0	N/A
1982	4600	7.0	34.0	1700	10.5	N/A
1983	N/A	N/A	N/A	1900	N/A	N/A
1984	4300	4.8	N/A	N/A	N/A	N/A
1985	4600	N/A	33.6	4200	N/A	N/A
1986	4700	N/A	31.2	N/A	N/A	N/A

Source : Defense Foreign Affairs Handbook

III. OVERVIEW OF ROK'S LOGISTICS

A. KOREAN WAR LOGISTICS

When the Korean War broke out, the ROK forces had only basic weapons which were considered adequate for national security. The heaviest weapons the ROK Army possessed were twenty-seven armoured vehicles and eighty-nine 105 mm howitzers which were of good design, but had short range. Fifteen percent of these weapons were useless, and thirty-five percent of the vehicles were out of commission. The ammunition on hand was sufficient only for a few days.

Since the ROK forces did not have adequate supply stocks, they were supplied by the U.S. forces during the war. From this point of view, the Korean War was the first example of supplier/recipient independence in a limited war due to a polarized world environment [Ref. 14: p. 5].

When the first unit, the 24th U.S. Infantry Division, deployed in the Korean Peninsula on 1 July 1950, the Far East Command (FEC) decided that the Eighth U.S. Army, located in Japan under FEC, was responsible for all logistical support for the forces in the ROK, except air and water transport. In addition, it decided to establish a base section in the ROK and maintain a minimum of a 45-day reserve of supplies in Japan, a figure later to be increased to 120 days [Ref. 15: p. 5].

Although the Eighth Army was not committed to combat, its logistical network was immediately set into motion. The directive to support ground forces in the ROK called for immediate utilization of stocks on hand at various depots in Japan.

When FEC alerted the divisions for deployment to the ROK, there were shortages of many required supplies. In the hurried effort to fill these shortages, established supply procedures were often ignored. This resulted in the issue of supplies without requisition and a loss of accountability. This way of issuing supplies also allowed unauthorized stock levels and receipt of supplies and equipment by units which were not authorized by Table of Organization (TO&E)

or other regulations. In other words, it became a "first-come-first-served" supply system.

Before deploying the U.S. forces to the ROK, the Logistical Plan for Eighth Army divisions was published as follows: [Ref. 16: p. 3]

- Units transported by air would carry a basic load of ammunition and a three-day supply of rations.
- Units moving by water would take two basic loads of ammunition and a 15-day supply of Classes I, II, III, and IV supplies. 5-day supply would be in the hands of troop units and 10-day supply in the division trains.
- Combat accounting of supplies would be placed in effect upon movement alert.
- The Eighth Army would provide automatic resupply of all Classes of supplies to the units in fifteen days.

At that time, the planners could not know how many units would be in the war, nor how quickly they would be alerted for the war. As the result of all the divisions deploying, the logisticians found it difficult to outfit later divisions with initial load levels.

For units deploying later, combat service support group made an intense search to locate the required ammunition loads. The earlier deployed units had taken more than their share of ammunition and other supplies. This condition resulted again, because the logisticians did not expect that all units would be deploying.

After the participation of United Nations forces in the Korean War, the mission of Eighth Army was directed to provide logistical support to all of them in the ROK. These multiple support taskings were imposed on a logistics system that was operating at far less than 100 percent efficiency. The system already suffered from a lack of properly trained personnel, equipment shortage, and personnel shortages.

During the offensive period, as the main operations were going on, the units to be supplied were diverted, and consequently, it made the supplies delayed to the other units. As a result of this, stock levels of ammunition at the supply points were rapidly reaching the critical state. Some of the items had dipped be-low the required stock level and as far as down to a one day supply of items remaining on hand.

As the time passed, the tactical situation was continuously changed because of the rapid movement of units. Although a forward supply distribution point was established, the delivery of the supplies was delayed, since, in addition to the rapid movement, units were also widely dispersed. Also, the long distance for supply made it more difficult because of the limitation of available transportation.

Consequently, during the Korean War, some problems encountered were: shortage of personnel and inadequately trained personnel in combat service; inadequate and often lack of war time policies for supporting units; improper command and responsibility alignment of support to support units.

B. ROK ARMY INVENTORY SYSTEM

The ROK logistics, as mentioned above, was dependent on the U.S. Army during the Korean War. The ROK Army neglected the importance of the logistic system because the U.S. forces undertook the responsibility for it during both the Korean and Vietnam Wars. Considerable efforts have been made to develop logistics plans to support credible strategic and tactical doctrines. However, the ROK Army still thinks of logistics as being of secondary concern.

Before the late 1960's, the ROK did not produce arms. The supplies from the U.S. under the Military Assistance Program (MAP) were an adequate source of resupply. Therefore, during that period, the ROK's logistic system was based on a "continuous refill system." This system allowed users to draw on stocks without regard for the cost. Reorders were paid for with MAP funds. As a result, financial responsibility was not enforced.

However, this system did not last long. As the threat from the DPRK increased because of the arms it produced, the ROK forces needed to get more capable and modernized weapons. The acquisition and maintenance costs of newer arms were too high, however.

Moreover, the changes in the conditions, such as the withdrawal of the 7th U.S. infantry division from the ROK on 21 March 1971, the fall of Vietnam to the Communists in 1975, and the plan to withdraw U.S. forces from the ROK by the Carter administration, pushed the ROK to begin arms production.

The first efforts to produce arms occurred in the mid-seventies. By these efforts, the domestic demand for arms was satisfied in 1975, and the surplus was exported to friendly nations. Since most of these arms were produced under license or by using the Technical Data Package from the U.S. rather than by original development, arms export was restricted by the U.S. government. Therefore, those industries produced only the planned quantity of the arms, equipment, etc., which were requested by the ROK MND. So, in this period, with the exception of critical items, the ROK logistic system became a "plan-produced supply support system within the budget."

In the late 1970's the U.S. security assistance policy toward the ROK underwent a tremendous change. When the ROK MND assumed increased responsibility for its own defense, it realized the need for a better and more efficient allocation of defense resources.

As a result, the ROK Army developed the Planning, Programming, Budgeting, Executing and Evaluation System (PPBEES), which was based on the U.S.'s Planning, Programming, Budgeting System (PPBS), to meet the ROK military needs [Ref. 17: p. 86].

The main idea of PPBEES is to establish a bridge between planning and programming and to feed back the result of performance evaluations for later use. This system also aims to develop a sound Defense Resource System by adding the execution and evaluation phases to the previous budget system. Consequently, the PPBEES is now applied to the logistic system in the ROK.

C. PROBLEMS IN ROK INVENTORY SYSTEM

The object of logistics is essentially the movement and support of forces in the field and to ensure the operation of weapons on the battlefield. Logistics generally can be classified as material management and physical distribution. Army logistics usually deals with material management that includes the following functions: requirement, procurement and acquisition, inventory control, distribution, maintenance and salvage of supplies. Basically, the primary purpose of logistics is to develop and maintain maximum combat power through the support of weapon systems.

Rapid changes in weapons and equipment in the recent period are increasing the importance of logistics. Also, its importance is focusing on the support and distribution of war materials during a future war, because the ROK now has the defense industries and has assumed responsibility for these functions.

In peace time, ROK Army logisticians continuously work to maintain the combat power of personnel and equipment, to prepare for a sudden invasion from the DPRK. However, when evaluating and discussing the results of the field training exercises, they always bring up the questions about how much ammunition, fuel, and the other supplies are needed, and whether it is possible to get those items in the quantity needed within the required time.

In the ROK Army, there are some expressions used to define the quantity of the supplies, for example: the basic load of ammunition, the required supply rate of ammunition, and control supply rate of ammunition. The basic load of ammunition means the amount that the unit could carry with its own transportation. The required supply rate of ammunition specifies the number of rounds per weapon per day needed to sustain operations of designated force without restriction for a specific period. Finally, the control supply rate limits the number of rounds which a weapon should use in a day or a certain period throughout the war.

Actually, it is impossible to figure out the real quantity of supplies needed during war time. Therefore, the designated numbers of those quantities have been estimated from simulations of war games, or from the Field Manual, or from actual data taken from the Korean War.

The other factor affecting the ROK Army system is the budget. After the success of the Economic Development Plans since 1961, the ROK has experienced rapid economic modernization transforming them from one of the most backward countries in Asia to one of the most advanced. As the economic situation has improved, the size of budget has grown larger and larger. Consequently, the budget for national defense has grown to around 30 percent of the national budget in the ROK.

To compensate for the U.S. withdrawal and for the modernization of the ROK forces, a larger budget is expected to be needed in the near future. Increasing the budget for national defense is, however, not desirable for the ROK government. Therefore, means to increase the effectiveness of current spending need to be found.

This budgetary limitation affects the ROK Army. Therefore, the quantity of supplies that can be maintained for a future war within a limited budget has become a major issue in the ROK Army. Since ammunition and fuel are critical materials during a war, this thesis is focused on the computation of the cost and the service level for these supplies which can be acquired within the present budget. Cost analysis is used to examine the efficiencies in service levels and budget utilization. This is illustrated by applying the method to an artillery battalion.

IV. COST ANALYSIS WITH MULTIPLE ITEMS

A. INVENTORY COST

The objective of inventory management is to have the appropriate amounts of raw materials, supplies, and finished goods in the right place, at the right time, and at low cost. Inventory costs are associated with the operation of an inventory system and result from action or lack of action on the part of management in establishing the system. They are the basic economic parameters to any inventory decision model, and the more relevant ones to most systems are itemized as follows: [Ref. 18: p. 13].

- purchase cost
- order/setup cost
- holding cost
- stockout cost

Note that for a particular inventory item, only those cost elements that are incremental (out of pocket) are pertinent in the analysis.

1. Purchase Cost

Purchase cost of an item is the unit purchase price if it is obtained from an external source, or the unit production cost if it is internally produced. The unit cost should always be taken as the cost of the item as it is placed in inventory. For purchase items, it is the purchase price plus any freight cost. For manufacturing items, the unit cost includes direct labor, direct material, and factory overhead. The purchase cost is modified for different quantity levels when a supplier offers quantity discounts [Ref. 18: pp. 13-14].

2. Order/Setup Cost

The order/setup cost originates from the expense of issuing a purchase order to an outside supplier or from internal production setup costs. This cost is usually assumed to vary directly with the number of orders or setups placed and not at all with the size of the order. The order cost includes such items as making requisitions, analyzing vendors, writing purchase orders, receiving materials, inspecting materials, following up orders, and doing the paperwork necessary to complete the transaction. The setup cost comprises the costs of changing over the production process to produce the ordered item. It usually includes preparing the shop order, scheduling the work, preproduction setup, expediting, and quality acceptance [Ref. 18: p.14].

3. Holding Cost

The holding cost, synonymous with carrying cost, subsumes the costs associated with investing in inventory and maintaining the physical investment in storage. It incorporates such items as capital costs, taxes, insurance, handling, shortage, shrinkage, obsolescence, and deterioration. Capital cost reflects lost earning power or opportunity cost. If the funds were invested elsewhere, a return on the investment would be expected. Capital cost is a charge that accounts for this unreceived return. Many states treat inventories as taxable property; so the more you have, the higher the taxes. Insurance coverage requirements are dependent on the amount to be replaced if property is destroyed. Insurance premiums vary with the size of the inventory investment. Obsolescence is the risk that an item will lose value because of shifts in styles or consumer preference. Shrinkage is the decrease in inventory quantities over time from loss or theft. Deterioration means a change in properties due to age or environmental degradation. Many items are age-controlled and must be sold or used before an expiration date. The usual simpifying assumption made in inventory management is that holding costs are proportional to the size of the inventory investment. On an annual basis, they most commonly range from 20 to 40 % of the investment. In line with this assumption is the practice of establishing the holding cost of inventory items as a percentage of their dollar value [Ref. 18: p. 14].

4. Stockout Cost

The stockout cost is the economic consequence of an external or internal shortage. An external shortage occurs when a customer's order is not filled; an internal shortage occurs when an order of a group or department within the organization is not filled. External shortages can incur backorder costs, present profit loss, and future profit loss. Internal shortages can result in lost production and a delay in a completion date. The extent of the cost depends on the reaction of the customer to the out-of-stock condition. If demand occurs for an item out of stock, the economic loss depends on whether the shortage is backordered, satisfied by substitution of another item, or canceled. In the one situation, the sales is not lost but only delayed a few days in shipment. Typically a company would expedite an emergency backorder for the item and assume any extra costs charged for the special service. In another situation, the sale is lost. The actual cost is less identifiable in this case but ranges from the apparent profit loss on the sale to loss of goodwill, which can be hard to specify. It can be seen that the stockout cost can vary considerably from item to item, depending on customer response or internal practice. It can be extremely high if the missing item forces a production line to shut down or causes a customer to go elsewhere in the future. The quantification of these costs has long been a difficult and unsatisfactorily resolved issue.

The central objective of inventory management is usually the minimization of the costs. Only those costs which change as the level of inventory changes should be considered in any analysis. For example, amounts expended on heating, lighting and security services for a warehouse should be disregarded if they do not change as stock levels vary [Ref. 18: pp. 14-15].

B. CONCEPT OF COST ANALYSIS

1. Conditions for the Use of Cost Analysis

In the typical continuous review inventory system, such as a deterministic model, a stochastic model, and a single period model, we can determine the optimal order quantity and the reorder point for a given time by minimizing the annual variable costs. However, it is, sometimes, not appropriate to apply these models to the real world inventory systems which have multiple items with constraints, like a budget constraint. Because of these constraints, the result which minimizes the total variable cost may not be always in the feasible region. Now, we turn our attention to the main point, namely a multi-item inventory system with a budget constraint.

After the Korean War, the ROK government increased its military expenditure as shown in table 2. Spending for national defense increased up to 30 percent of the national budget since 1978. With the added burden caused by the U.S. decision to withdraw its forces from the ROK, the pressure to expand defense spending has increased. Because of this, the government has put tight controls on any spending growth.

In the future, war is likely to last for only a short period of time, because of the development of high-tech arms and their applications in war. If there is another war, on-hand stocks may be the only support available. Therefore the support of the logistics system becomes a critical problem.

To support the ROK Army's ability to fight, the conditions mentioned above are extremely critical. Therefore a proper model must be developed to explore the possible outcomes. This model must reflect the following circumstances and assumptions:

- The next war will be conventional.
- The war will not last more than 5 days.
- The resupply of critical items will take 2 days after the war breaks out and can occur only once during the war period.
- There are sufficient vehicles to support the resupply efforts.
- No substitutions for critical items are allowed.
- The demands for the critical items are independent and normally distributed.
- There is a budget constraint which limits the size of inventory.

In this thesis,

- We concentrate on fuel and ammunitions as our critical items.
- We use a 105 mm artillery battalion to demonstrate the models.
- The battalion has maintenance ability and repair parts for 2 weeks.

The objective is to compute the present service levels of critical items within the given budget size, and to determine whether the budget is being used effectively. The cost analysis with the Lagrangian multiplier method is used.

2. Cost Analysis Approach

In inventory problems, the Lagrange multiplier is the value or cost per unit of resources: It represents the amount by which the minimum cost can be reduced by adding one additional unit of limiting resource. The Lagrange multiplier can be used to consider imputed values or shadow prices of resources.

To minimize a function $f(X_1,..., X_n)$ subject to an equality constraint $g(X_1,..., X_n) = a$, where both functions are continuous and differentiable, we have to find a stationary point for the unconstrained function

$$L(X_1,..., X_n,\lambda) = f(X_1,..., X_n) + \lambda[g(X_1,..., X_n) - a]$$

where

$$\lambda = \text{nonnegative Lagrange multiplier}$$

That is, we look for a point that satisfies

$$\frac{\partial L}{\partial X_j} = \frac{\partial f}{\partial X_j} + \lambda \frac{\partial g}{\partial X_j} = 0$$

$$\frac{\partial L}{\partial \lambda} = (g - a) = 0$$

where

$$j = 1, 2, ..., n$$

By simultaneously solving the above equations for X_j and λ the minimum point $f(X_1,..., X_n)$ if obtained (Ref. 18: pp. 296-297).

In general, when the objective function is to minimize the expected number of stockouts for the critical items during a special period, the problem can be stated mathematically as

Minimize

$$K = \sum_{i=1}^{n} t_i \int_{B_i}^{\infty} (M - B_i) f_i(M) dM \tag{1}$$

Subject to

$$\sum_{i=1}^{n} C_i B_i = S \tag{2}$$

where

n = the number of different items

t_i = priority or weight of item i

M = the number of item i demanded

$f_i(M)$ = the probability density function of M

B_i = the number of item i which is on-hand

$M - B_i$ = size of stockout

C_i = unit cost for the item i

S = the total budget

Since the budget constraint is binding we obtain:

$$L = \sum_{i=1}^{n} t_i \int_{B_i}^{\infty} (M - B_i) f_i(M) dM + \lambda \left[\sum_{i=1}^{n} C_i B_i - S \right]$$

In this thesis, we are concerned with only two critical items -- ammunition and fuel. Therefore the value of n is 2. To solve the formula, we will take the partial derivatives of L with respect to B_1, B_2 and λ, which are set equal to zero.

$$L = \sum_{i=1}^{2} t_i \int_{B_i}^{\infty} (M - B_i) f_i(M) dM + \lambda \left[\sum_{i=1}^{2} C_i B_i - S \right] \tag{3}$$

For the partial derivative of B_1, we get

$$\begin{aligned}
\frac{\partial L}{\partial B_1} &= \frac{\partial}{\partial B_1} [t_1 \int_{B_1}^{\infty} (M - B_1) f_1(M) dM + \lambda C_1 B_1] \\
&= - t_1 \int_{B_1}^{\infty} f_1(M) dM + \lambda C_1 \\
&= - t_1 P_1(M > B_1) + \lambda C_1 \\
&= 0
\end{aligned}$$

Therefore

$$\lambda = \frac{t_1 P_1(M > B_1)}{C_1}$$

By the same procedure, we get

$$\lambda = \frac{t_2 P_2(M > B_2)}{C_2}$$

From these two formulas, we get

$$\lambda = \frac{t_1 P_1(M > B_1)}{C_1} = \frac{t_2 P_2(M > B_2)}{C_2}$$

or

$$\frac{P_2(M > B_2)}{P_1(M > B_1)} = \frac{t_1}{C_1} \times \frac{C_2}{t_2} = \frac{t_1}{t_2} \times \frac{C_2}{C_1} \tag{4}$$

where

$P_i(M > B_i)$ = probability of stockout of item i

From the partial derivative of λ, we get

$$\frac{\partial L}{\partial \lambda} = C_1 B_1 + C_2 B_2 - S = 0$$

$$C_1 B_1 + C_2 B_2 = S \tag{5}$$

It means the ratio of a stockout probability of an item multiplied by its weight over the cost should be equal for each item. That is, if the actual ratio of two stockout probabilities is different from the mathematical computation calculated by equation (4), the budget should be reallocated to optimize its effectiveness. We can adjust the stockout probabilities of other items in the multi-items inventory system within a budget constraint by changing the stockout probability of an item. In this case, the budget is equal to the sum of the number of each item multiplied by each cost.

3. A Procedure of Applying Cost Analysis

First, we have to compute the required quantity for the critical items during the future war period (in this thesis, for ammunition and fuel during 5 days). We can figure them out on the basis of the control supply rate (CSR).

Second, we compute the total cost of each item by multiplying the cost by the quantity needed for the period.

Third, we compute the sum of each total cost. This sum is equal to the budget for the items - in our case, ammunition and fuel.

Fourth, we find the demand for those items. We can use the data from the Korean War and some assumptions.

Fifth, we consider the type of demand generation probability distributions. In this thesis, we assume the normal distribution is fitted for both items.

Sixth, we compute the service level for each item.

Seventh, we give them a priority to purchase or acquire the item by its importance to perform a war. In this thesis, we assume that the priority is equal between ammunition and fuel.

Finally, we ensure that the budget is being effectively used. If the budget is not being used effectively, we have to find out new service levels which satisfy the conditions (4) and (5) by iterative method.

We now illustrate this procedure.

C. AN ILLUSTRATION

1. Problem Definition

As the U.S. withdrawal from the ROK is in progress, the ROK Army must consider the effective operation of artillery which is suitable to the Korean terrain characteristics and which best satisfies the mission. During the Korean War, artillery played a major role to support the infantry forces and it is still evaluated as a main ground power in a future war.

An analysis of the last war, however, shows that the ROK artillery did not perform its mission effectively because it lacked repair parts, maintenance ability, and ammunition prior to the arrival of U.S. support.

To prepare for self defense without U.S. support, the ROK government has invested a large portion of its budget since the early seventies in the development of defense industries. As the defense industries developed, the problems caused by the lack of repair parts and maintenance ability have been overcome. Nevertheless, the problem of ammunition supply still remains unsolved. An additional problem that of having adequate stocks of fuel, must also be solved.

A result of developing the defense industries has been the modernization of artillery. A new gun barrel for the 105 mm howitzer was developed, which increased the range from 12 km to 15 km. Additionally, industry developed a new model, KH178 105 mm Howitzer, which is very suitable to the Korean situation, and has been produced since 1984. It is now in service in the ROK Army, and can use all the current standard 105 mm ammunitions. Table 3 lists pertinent data on the weapon.

Table 3. CHARACTERISTIC OF 105 MM KH 178 LIGHT HOWITZER

Specifications	Descriptions	Specifications	Descriptions
Calibre	105 mm	Rate of Fire	15 rpm (max) 5rpm(sustained)
Max Range	HE : 14.7 km RAP: 18.0 km	Towing Vehicle	2 1/2 ton truck

Source : Jane's Armour and Artillery 1984 - 1985

According to the current operation plan, if war breaks out, the unit should act as described in the Standing Operating Procedures (SOP). The SOP directs them to arrange their forces into the designated position, and bring the ammunition from their own stores. On the basis of the ROK Army regulation, the quantity of the supplies to be maintained in the units is specified by the Control Supply Rate (CSR). For example, the supplies which should be on hand are as much as the unit can use during a war for 3 days by CSR. Table 4 shows an illustration of CSR.

Table 4. EXAMPLE : CONTROL SUPPLY RATE PER UNIT

Subject	Number/unit	Description	C S R
105mm Howitzer	18	Ammunition	180 rounds/day
2 1/2 ton Truck	61	Fuel	41 gallons/day

For computing the demand rate for ammunition, we can use any of three bases: war game result, Field Manual (FM) data, or Korean war data. Since the war game data is dependent upon the situation, and FM data were not drawn from actual experience, Korean War data is the best choice and is used for the basis of the computation in this thesis. The data assumes a consumption rate for a modern war will be greater than the historical Korean War figures. This demand is deemed to have a normal distribution, with a mean which is found by multiplying 2.5 times the mean of day of supply during the Korean War, and a standard deviation as the square root of mean. Table 5 shows the day of supply during the Korean War for 105 mm Howitzer ammunition.

Table 5. DAY OF SUPPLY IN THE KOREAN WAR [Ref. 19: p. 35]

Weapon	Far East Command						Average
	1July50	14July50	6Oct50	1Sep51	1Nov51	1July52	
105 mm Howitzer	30	180	30	40	55	55	65

There are no data available for fuel use during the Korean war. Therefore, we assume the demand is normally distributed, with a mean of 26 gallons per day, which is the amount considered as the average usage rate at present time in the ROK, and with a standard deviation of 8.7.

For the purpose of illustration, it may be useful to first present the statistical consideration, second compute the cost and service level, and finally analyze the result of the computation.

2. Statistical Consideration

Since it is impossible to resupply war materials more than one time throughout the war period, and the demand is noncontinuous, changeable, and short-time lived, the single order quantity model is suitable. (Appendix A)

In general when an item in multi-items inventory system are intended for only internal use with no generation of revenue, the selection of single order size is based on the lowest expected cost. The cost components are order cost, purchase cost, stockout cost and salvage value.

The following formula is for the expected cost of a single order for a continuous distribution [Ref. 18: pp. 310-312].

$$EC = C + PQ + A\int_{Q}^{\infty}(M - Q)F(M)dM - V\int_{0}^{Q}(Q - M)F(M)dM$$
$$= C + PQ + (A - V)\int_{Q}^{\infty}(M - Q)f(M)dM + V(\overline{M} - Q)$$

where

EC = expected cost

C = order cost

P = unit purchase cost

Q = single order quantity

A = stockout cost per unit

$M =$ demand

$M - Q =$ size of stockout

$f(M) =$ probability density function of demand

$V =$ salvage value

To determine the minimum expected cost for continuous distribution requires taking the derivatives of expected cost with respect to the order size and setting it equal to zero. It can be stated mathematically as

$$\frac{dEC}{dQ} = P - (A - V)P(M > Q) - V = 0$$

Therefore

$$\begin{aligned} P(M > Q) &= \frac{P - V}{A - V} \\ &= \text{optimum stockout probability} \end{aligned} \tag{6}$$

This formula implies that if purchase cost is equal to or greater than the stockout cost, the desired stockout probability is 1. Under these conditions, no orders would be instituted until a known demand existed. Also, if an item has no salvage value, the optimum probability of stockout is $P(M > Q) = \frac{P}{A}$. Thus, if the demand for the item is normally distributed with a known mean $\overline{M}$ and standard deviation σ, the following expression determines the lowest expected cost single order quantity:

$$\begin{aligned} Q_0 &= \overline{M} + Z\sigma \\ &= \text{optimum single order size} \end{aligned} \tag{7}$$

where Z is the normal standard deviate obtained from the normal table for the stockout probability of $P(M > Q)$.

However, the most common situation is when an organization does not know its stockout cost or feels very uneasy about estimating it. Under this condition, it is common for management to set service levels which indicate the ability to meet customer demands from stock [Ref. 18: p. 211].

Figure 1 shows the concept of stockout probability. In this figure, the portion on the right side of Q under the curve is the probability of stockout. Since there is no salvage value for either items at the end of the war period, we can calculate the service level by using the following formula.

$$\begin{aligned} \text{Service level} &= 1 - P(M > Q) \\ &= P(M \leq Q) \\ &= P(\frac{M - \overline{M}}{\sigma} \leq \frac{Q - \overline{M}}{\sigma}) \\ &= P(Z \leq \frac{Q - \overline{M}}{\sigma}) \end{aligned} \tag{8}$$

Returning to the main problem, we have two items -- ammunition and fuel -- demands for which are normally distributed. Since we know the value of Q, $\overline{M}$ and σ, we can get the Z value from the standard normal distribution table.

3. Computation of Cost and Service Level for each Item

We now consider how to compute the cost and the service level. In our problem, it is very important to make an economic decision for the logistic support because of the budget constraint. In the ROK, since the purchase costs are about 113 U.S. dollars for a round of 105 mm Howitzer and about 4 U.S. dollars for a gallon of fuel, we can compute the total cost by using the CSR of each item.

a. Total Cost

The acquired rounds of ammunition during the war time can be computed as

$$180 \text{ rounds/day Howitzer} \times 5 \text{ days} \times 18 \text{ Howitzers} = 16{,}200 \text{ rounds}$$

Therefore, the total cost is

$$16{,}200 \text{ rounds} \times \$113/\text{ round} = \$1{,}830{,}600$$

The required gallons of fuel during the war period is

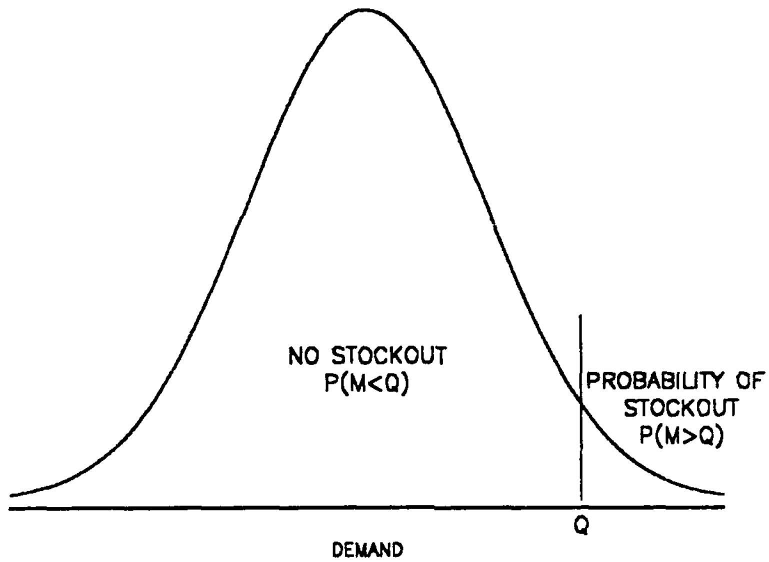

Figure 1. Example: Density Function Curve

$$41 \text{ gallons/ day truck} \times 5 \text{ days} \times 61 \text{trucks} = 12{,}505 \text{ gallons}$$

Therefore, we get the total cost as

$$12{,}505 \text{ gallons} \times \$4/\text{ gallon} = \$50{,}020$$

To find the total budget, we can compute the sum of the total costs for each item by using Equation (5). From this equation,

$$\begin{aligned} S &= C_1Q_1 + C_2Q_2 \\ &= \$1{,}830{,}600 + \$50{,}020 \\ &= \$1{,}880{,}620 \end{aligned}$$

b. Service Level

For ammunition, the demand is normally distributed with a mean 162.5 rounds/day and standard deviation 12.75. Figure 2 shows the demand density function of ammunition. To calculate the service level, we use Equation (8).

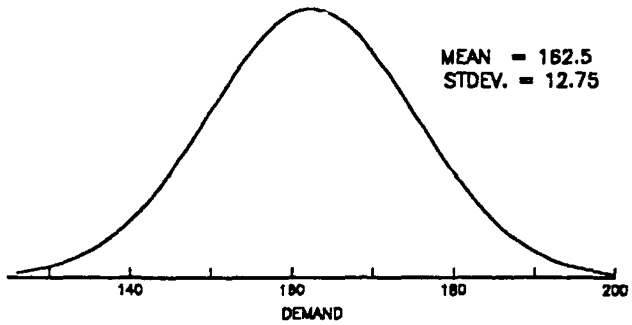

Figure 2. Example: Ammunition Demand Density Function

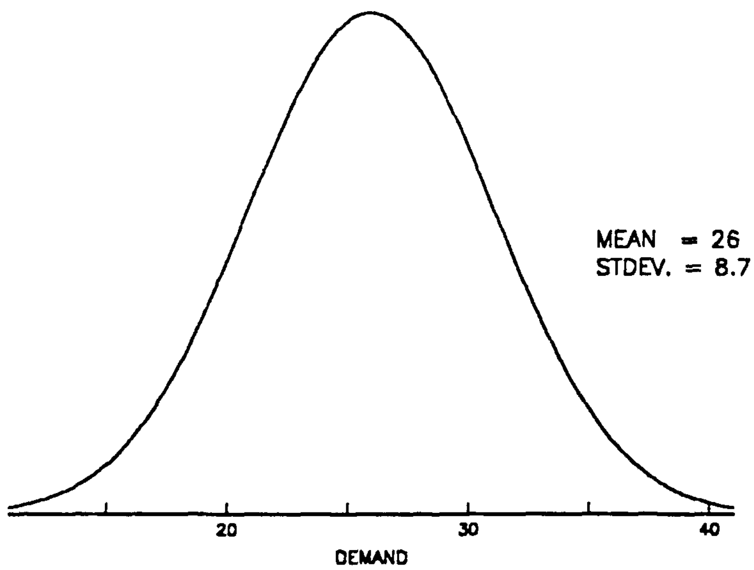

Figure 3. Example: Fuel Demand Density Function

$$
\begin{aligned}
\text{Service Level} &= P(Z \le \frac{Q - \overline{M}}{\sigma}) \\
&= P(Z \le \frac{180 - 162.5}{12.75}) \\
&= P(Z \le 1.3725) \\
&= 0.9151
\end{aligned}
$$

That is, the stockout probability of ammunition is 1.00 - 0.9151 = 0.0849 or 8.49 percent. This means that the probability the demand exceeds the quantity of CSR is 8.49 percent.

Since the demand is normally distributed with a mean 26 gallons / day and a standard deviation 8.7, as Figure 3, we can get the service level as

$$
\begin{aligned}
\text{Service Level} &= P(Z \le \frac{Q - \overline{M}}{\sigma}) \\
&= P(Z \le \frac{41 - 26}{8.7}) \\
&= P(Z \le 1.7241) \\
&= 0.9577
\end{aligned}
$$

That means the probability of stockout is 1.00 - 0.9577 = 0.0423 or 4.23 percent. The results say that if we provide ammunition and fuel in accordance with the CSR, the service level will be 91.51 percent for ammunition and 95.77 percent for fuel. The total system service level, definded as the probability will have enough fuel AND enough ammunition, is 87.64 percent ($0.9151 \times 0.9577 = 0.8764$).

4. Analysis

In this thesis we are interested in three points: how much funding is needed, what are the service levels related to the funding level, whether the budget is being used effectively.

For the funding we need S1,880,620 as computed by CSR, and the service level, as previously calculated, is 91.51 percent for ammunition and 95.77 percent for fuel. With these results, we can examine whether the budget is being used effectively by using the formula:

$$\lambda = \frac{t_i P_i(M > Q_i)}{C_i} \tag{9}$$

where

t_i = priority of item i

$P_i(M > Q_i)$ = stockout probability of item i

C_i = purchase cost of item i

When a war breaks out, we need on average 2925 rounds and 1586 gallons for a day. Assuming the importance of the 2925 rounds is equal to that of the 1586 gallons, and setting the priority of fuel at 1, we get the priority of ammunition, which is 0.54. Subscript 1 is used to indicate ammunition, and subscript 2 indicates fuel. Thus:

$$t_1 = 0.54$$

$$t_2 = 1$$

At this point all the data is in hand to calculate the optimal service levels within the budget. The first step is to calculate the "CSR-based service level ratio." This is done by taking the ratio of the probabilities that demand exceeds the CSR quantity for the critical items. Thus:

$$\frac{P_2(M > Q_2)}{P_1(M > Q_1)} = \frac{0.0423}{0.0849} = 0.4982$$

The next step is to find the optimizing ratio based on the budget, which we term the "budget ratio." From the equation (4) we get:

$$
\begin{aligned}
\frac{P_2(M > Q_2)}{P_1(M > Q_1)} &= \frac{t_1}{C_1} \times \frac{C_2}{t_2} \\
&= \frac{0.54}{\$113} \times \frac{\$4}{1} \\
&= 0.0191
\end{aligned}
$$

Thus the CSR-based ratio is greater than the budget ratio of stockout probabilities. In order to optimize the allocation of the budget the ratios must be equal. Therefore funds must be shifted from ammunition to fuel. By equating the two values, we increase the stockout probability of ammunition and decrease that of fuel. Since in this case the budget constraint is binding, we must adjust the stockout probabilities through an iterative process to find the optimal point. Table 6 shows the iterative computations.

Table 6. COMPUTATION OF RATIO FOR STOCKOUT PROBABILITIES

Level	Q_1	Q_2	$P_1(M > Q_1)$	$P_2(M > Q_2)$	Ratio
1	180.000	41.000	0.08492	0.04233	0.49823
2	179.000	49.336	0.09780	0.00378	0.03783
3	178.700	51.837	0.10115	0.00150	0.01483
4	178.780	51.170	0.10084	0.00190	0.01884
5	178.783	51.145	0.10081	0.00190	0.01885
6	178.785	51.128	0.10077	0.00192	0.01902
7	178.786	51.120	0.10076	0.00193	0.01912
8	178.787	51.112	0.10074	0.00194	0.01926

The above table shows that the closest ratio to the sought mathematical value is at level 7. This means that the optimal quantity of CSR is 178.786 rounds of ammunition and 51.120 gallons of fuel. The optimal service level for ammunition is therefore 0.89924, while that of fuel is 0.99807. The total system service level is 89.75 percent, an increase of over 2 percent.

To achieve level 7, the funds which must be shifted from ammunition to fuel is calculated as:

$$(180 - 178.786)\text{rounds/Howitzer day} \times 18\text{Howitzers} \times 5\text{days} \times \$113/\text{round}$$

$$= \$12,346.38$$

or, conversely,

$$(51.120 - 41)\text{gallons/truck day} \times 61\text{trucks} \times 5\text{days} \times \$4/\text{gallon} = \$12,346.4$$

In this example the improvement by using our method was considerable. It must be stressed, however, that these are not actual data, and that actual data may require insignificant changes to realize the optimal levels. Table 7 summarizes the war fighting capability (system service level) before and after applying the model to our data.

Table 7. WAR FIGHTING CAPABILITY

Level	Service Level		Capability
	Ammunition	Fuel	
CSR-based	0.9151	0.9577	0.8764
Optimized	0.8992	0.9981	0.8975

Thus by changing the service levels to make the budget more effective, a gain of 0.0211 percent is realized. Note that this decreases the risk of being short by 17 percent (2.11 / (1.00 - 0.8764) = 17.07). This is calculated as the product of the service levels. From these results, we can say that when the budget is reallocated to make the CSR-based ratio equal to the budget ratio, we can increase the war fighting capability by optimizing the effectiveness without increasing the present budget.

V. CONCLUSION

Based on the experience of the Korean War, it is natural that the ROK Army should focus on more effective and efficient management of defense resources. Since the U.S. forces provided logistic support for both the Korean and Vietnam Wars, the ROK Army gained little experience or data on logistics. As a result, their logistics system has been very dependent on the Field Manual or on the records acquired from other countries based on other wars. Such facts are not well fitted to the Korean situation.

Moreover, the atmosphere of detente between the U.S. and the Soviet Union, and the collapse of the Berlin Wall causes the U.S. government to reduce its military budget. Consequently, the U.S. plans to withdraw its forces from ROK. This plan forces the ROK government to increase funding for their national defense.

Therefore, it is very important that the budget be used effectively to accelerate the modernization of forces so as to maintain a military balance in the Korean Peninsula, without straining its budget. Furthermore, a future war could occur with very short notice, and end rapidly since both Koreas have high-tech weapon systems. As a result, it is critically important that the ROK logistics inventory system make maximum use of its limited budget to provide the best possible service levels for war critical items.

Because the size of the budget is constrained, we must effectively allocate it so as to adjust the critical item service levels, thereby maximizing our war fighting capability.

A main problem of this study is that since we cannot calculate the demand for the critical items perfectly, we have to depend on the data from the last war. This decreases the credibility of the study. To improve this weakness, we could apply the data from the simulation of war game models, which are designed to simulate the Korean terrain characteristics and military situation. This data was not available for this study, however.

It is emphasized that the cost analysis method is suggested not for merely saving the budget, but for using it most effectively in preparation for a future war. Judgement will always be required because of the difficulties in assessing the exact essentiality of critical items, and to determine if the assumptions coincided with the real situation.

APPENDIX A. SINGLE ORDER QUANTITY

The single order quantity model is concerned with the planning and control of inventory items that are purchased only once during a time period, or for which only one production run may be initiated.

This model is very well suited to demand that is noncontinuous, changeable, and short-lived. It is specifically applicable to the following two categories of demand: (1) demand which exists for an item at frequent intervals and (2) uncertain demand which exists for a short-lived item at frequent intervals. The first category is typified by promotional and fad items ordered by retail stores and by spare parts for maintenance repair. The second category is associated with highly perishable items.

Due to its common association with the second category, the single order quantity problem is frequently referred to in the literature as the Christmas tree problem or the Newsboy problem.

Single order quantity items have a demand pattern with a limited sales (or usage) period. An item is order at the beginning of the period, and there is no opportunity for a second order during the period, since a second order would not arrive before the end of the period.

The single order quantity problems can be classified according to source, demand, and lead time. The source of single order quantity may be self-supply or outside supply. Self-supply exists when the organization produces the item itself, whereas outside exists when another organization is the supply source. With self-supply, the lead time is mainly composed of production scheduling, manufacturing, and assembly time. With outside supply, the lead time also includes the transit and receipt times.

The determination or estimation of the demand is critical in dealing with a single order. If the demand is known, the problem is simplified. If the demand follows some specified or empirical distribution, the problem can be solved by the techniques of decision making under risk. With no information concerning the demand, it becomes necessary to do market analysis or market research.

The lead time has a different significance with the single order than with the repeat order. With a repeat order and on going demand, the lead time is a complication, since demand occurs during the lead time. With a single order, there is no demand, or at any rate, there is no stock available to satisfy demand during the lead time. The lead time is thus the waiting time until goods are available to meet demand. Until the goods arrive, there is no stock available. If the lead time is longer than expected, some sales may be lost. If the lead time is shorter than expected, the stock is available prior to demand.

A. KNOWN DEMAND, KNOWN LEAD TIME

When the demand is known and the lead time is known, there is no single order inventory problem. The quantity of goods ordered matches the demand, and they arrive on the day of demand origination. A condition of certainty exists which rarely occurs in practice. For this condition to exist, all demand must result in backorders from patient customers, or all planning must be perfect with no unusual occurrences or delays.

B. KNOWN DEMAND, VARIABLE LEAD TIME

Since the demand is known, the size of the single order is known. With a variable lead time, the decision maker wants to ensure that the order is received prior to demand, so there is no idle production time or lost sales. If no lost sales are to be tolerated, orders are placed prior to the maximum possible lead time. If a lead time distribution can be ascertained, a lead time can be selected which has a high probability of arrival prior to demand. Alternatively, if the demand is fixed regardless of when the goods are delivered, a late delivery only delays an activity. This situation could exist in the construction of a building, where a delivery delay would only result in a construction delay.

When self-supply exists, the variable lead time is a result of uncertainties in scheduling and in the production processes. A service level policy on the lead time can be obtained from a PERT analysis.

C. VARIABLE DEMAND, KNOWN LEAD TIME

When the demand is variable and the lead time is known, the single order inventory problem is in ascertaining the order size. If the demand is not known but the probability distribution of demand is available, the problem can be solved as decision making under risk. The order size that results in the largest expected profit or lowest expected cost is selected.

The procedure for decision making under risk is to determine the demand strategy with the optimum expected value. The probability that the demand will be less than or equal to the single order quantity for a discrete distribution is as follows:

$$P(M \leq Q) = \sum_{M=0}^{Q} P(M) = 1 - \sum_{M=Q+1}^{M_{max}} P(M)$$

where

Q = single order quantity in units

M = demand in units(a random variable)

$P(M)$ = probability of a demand of M units

M_{max} = maximum demand in units

The probability that the demand will exceed the single order quantity is as follows:

$$P(M > Q) = \sum_{M=Q+1}^{M_{max}} P(M) = 1 - \sum_{M=0}^{Q} P(M)$$

The procedure for calculating the expected value of each discrete demand strategy Q_i is as follows:

$$E(Q_i) = P(M_0)F(Q_iM_0) + P(M_1)F(Q_iM_1) + \dots + P(M_n)F(Q_iM_n)$$
$$= \sum_{j=0}^{n} P(M_j)F(Q_iM_j)$$
$$= \text{expected value of strategy } Q_i$$

where $F(Q_iM_j)$ is the outcome of following the demand strategy Q_i when the actual demand is the state of nature M_j. The determination of outcomes can take on two forms, depending on whether the amount ordered (Q_i) is less than or greater than the demand level (M_j). When the outcomes are expressed in profit or benefit terms, the following relationships apply:

$$F(Q_iM_j) = Q_jJ \qquad \text{for } Q_i \leq M_j \text{ (understock condition)}$$

$$F(Q_iM_j) = M_jJ - (Q_i - M_j)l \qquad \text{for } Q_i > M_j \text{ (overstock condition)}$$

where

J = unit profit or benefit

l = loss from disposition of unutilized unit

Q_i = single order quantity of i units

M_j = demand level of j units

$Q_i - M_j$ = number of units overstocked

When outcomes are expressed in cost or sacrifice items, the following relationships apply:

$$F(Q_iM_j) = Q_iP \qquad \text{for } Q_i \geq M_j \text{ (overproduction condition)}$$

$$F(Q_iM_j) = Q_iP + (M_j - Q_i)A \qquad \text{for } Q_i < M_j \text{ (underproduction condition)}$$

where

P = unit cost

A = stockout cost per unit

$M_j - Q_i$ = size of stockout in units

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